Met.O.880
METEOROLOGICAL OFFICE

the meteorological magazine

JANUARY 1975 No 1230 Vol 104
Her Majesty's Stationery Office

METEOROLOGICAL OFFICE Met.O.880

THE METEOROLOGICAL MAGAZINE

Vol. 104, No. 1230, January 1975

551.515.83:551.526.6:551.571.4

THE WARMING AND MOISTENING OF COLD AIR MASSES BY THE SEA

By K. GRANT

Summary. An empirical formula for the change in temperature of cold air crossing a warmer sea is based on a hypothesis adopted for the sea-to-air heat-transfer coefficient. The formula is tested by using routine synoptic observations made in cold airstreams reaching the British Isles. A formula, due to J. A. Businger, for the increase in humidity mixing ratio is also tested.

Practical details are given of the use of the formulae.

Introduction. Blackall[1] has recently produced the following empirical formula for the increase in temperature of cold air as it crosses a warmer sea:

$$T = T_0 + (1 - \exp(-12t/d))\,(T_s - T_0). \qquad \ldots (1)$$

(All symbols used are defined in Appendix I.)

This paper presents the results of an attempt to find an alternative empirical formula for T which would give smaller root-mean-square (r.m.s.) errors than the above equation, and also the results of a test of Businger's[2] theoretical formula for humidity change.

The prognostic equations for temperature. The working hypothesis was adopted that the heat-transfer coefficient C_H could be represented by

$$C_H = \beta \left(\frac{T_s - T}{\bar{T}}\right)^{\alpha},$$

that is, that C_H is proportional to a constant unknown power of the sea–air temperature difference divided by the mean air temperature. By using an argument similar to that used on page 66 of Blackall's paper,[1] but starting from the basic equation $H = c_p \rho C_H V(T_s - T)$, this hypothesis leads to the prognostic equations

$$T = T_0 + [1 - \exp(-\rho g \beta s/d)]\,(T_s - T_0) \qquad \ldots (2)$$

if $\alpha = 0$, and

$$T = T_0 + \left[1 - \left(1 + \frac{\alpha\beta\rho g}{\bar{T}^{\alpha}} \cdot \frac{s}{d} \cdot (T_s - T_0)^{\alpha}\right)^{-1/\alpha}\right] (T_s - T_0) \qquad \ldots (3)$$

if $\alpha \neq 0$.

Determination of α and β from Blackall's synoptic data. Blackall's data were examined, and, by making use of 23 of his sets of initial conditions covering 15 different days, revised estimates of terminal temperatures and dew-points were made, with a view to obtaining the temperatures right on the coast, and the dew-points a little way inland. It was hoped that this would reduce the effects of the diurnal modification of temperature over land and the possibly strong vertical gradient of humidity at low levels over the sea and coastal areas.

For various values of α the minimum r.m.s. error and the associated optimum value of β were calculated, a range of β being used for each value of α. From these the optimum value of α and the corresponding value of β for overall minimum r.m.s. error in the forecast final temperature T were found. The sea-level air density ρ was obtained by assuming a constant sea-level pressure of 1013 mb in all cases, with $\overline{T}$ equal to $(T + T_0)/2$. The gas constant R was taken as 287 J kg^{-1} K^{-1} (the value for dry air) and g as 9·81 m s^{-2}. The results are shown in Figure 1.

An overall minimum r.m.s. error of 0·6 degC is seen to occur at $\alpha \approx 2$. On the evidence of this analysis it was decided to adopt a value of exactly 2 for α, and the corresponding value of 3·8 for β (note that the optimum value of β changes substantially for the various values of α which were tested).

The effect of using virtual temperature was similarly explored. A minimum r.m.s. error of 0·57 degC at $\alpha = 2{\cdot}2$ was found (with $\beta = 3{\cdot}2$ for $\alpha = 2$). It was concluded that no significant benefit was to be gained by using virtual rather than dry-bulb temperatures, at least in these circumstances when air temperatures are around or below 5°C.

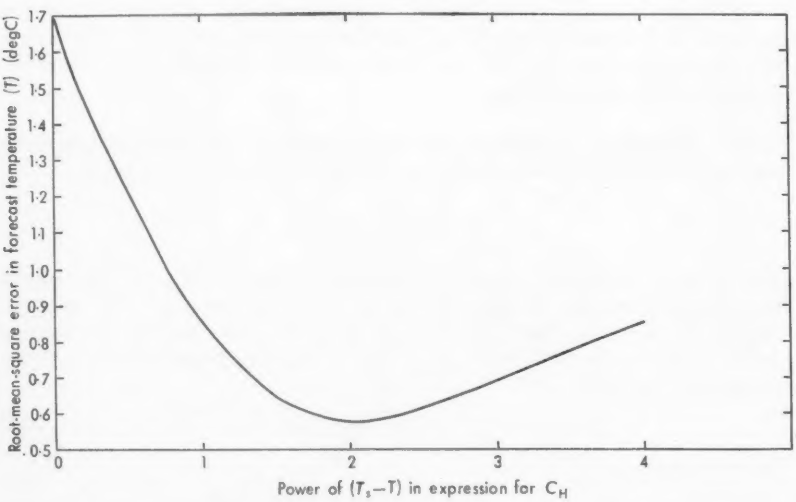


FIGURE 1—EFFECT ON ACCURACY OF FORECAST TEMPERATURE OF VARYING α IN $C_H = \beta\,(T_s - T_0)^\alpha/T^\alpha$

The β which gives minimum root-mean-square error in forecast temperature is used for each value of α.

The explicit formula for temperature. When the values of α and β determined above are substituted, the air density ρ is replaced by $p_s/R\overline{T}$, the fetch s is expressed in terms of units of degrees of latitude (1 degree of latitude $\approx$ 60 nautical miles $\approx$ 111 km), and the depth d in millibars, equation (3) becomes

$$T = T_0 + \left[1 - \left(1 + \frac{N(T_s - T_0)^2 s}{d}\right)^{-\frac{1}{2}}\right](T_s - T_0), \qquad \ldots (4)$$

where $N = 2{\cdot}92 \times 10^4 p_s/\overline{T}^3$ (p_s being expressed in millibars and $\overline{T}$ in kelvins).

N varies slowly with temperature and pressure as shown in Table I.

TABLE I—VARIATION OF N WITH TEMPERATURE AND PRESSURE

$\overline{T}$ °C	p_s (mb) 980	1000	1020	1040
		N		
+10	1·26	1·29	1·31	1·34
+ 8	1·29	1·31	1·34	1·37
+ 6	1·32	1·34	1·37	1·40
+ 4	1·34	1·37	1·40	1·43
+ 2	1·37	1·40	1·43	1·46
0	1·40	1·43	1·46	1·49
− 2	1·43	1·46	1·49	1·52
− 4	1·47	1·50	1·53	1·56
− 6	1·50	1·53	1·56	1·59
− 8	1·53	1·57	1·60	1·63
−10	1·57	1·60	1·63	1·67

Businger's theory of humidity-mixing-ratio change. On the assumption that $C_E = C_H$ and that r is constant with height through the convection layer, it might be expected that the formula for the evaporative flux E would be analogous to that for H. Businger, in Section 5.10 of Fleagle and Businger,[2] showed that this is not so, the difference being that only the temperature, not the mixing ratio, determines the depth of dry convection.

Businger's formula is

$$r = r_0 + Z(r_s - r_0), \qquad \ldots (5)$$

where Z is a factor depending on the temperature increment through the relations

$$Z = 1 + \frac{1 - Y}{Y} \ln (1 - Y)$$

$$\text{and } Y = (T - T_0)/(T_s - T_0).$$

An interesting point here is that when Y is in the range 0·4 to 0·9 (as in practice it quite often is), Z is very nearly equal to $Y - 0{\cdot}2$. This implies that if Frost's[3] temperature formula $T = T_0 + 0{\cdot}6\,(T_s - T_0)$ (where T_0 here is the unmodified initial surface air temperature) is accepted as being sufficiently accurate, then the appropriate constant in his mixing-ratio formula is not 0·6 but 0·4.

Test of Businger's formula based on the use of dew-point data. Businger's formula was checked by using the dew-point and temperature data for the 23 occasions mentioned above. The mean error in dew-point was −0·36 degC and the standard deviation of the errors was 0·95 degC. These values compare with Blackall's values (relative to his own terminal values) of −0·6 degC and 2·1 degC respectively, and show an improvement in r.m.s. error which is significant at the 0·1 per cent level.

During this work it was noticed that dew-points at stations actually on the coast often tended to be higher than those reported inland by about 1–2 degC. Most of this change appeared to arise close to the coast.

An independent check of performance. Tests of the performance for the British Isles of equations (4) and (5), as well as that of other methods, were carried out by Hedge[4] who used independent data and trajectories determined from forecast charts as well as from actual charts. The results for actual charts are shown in Table II.

Table II shows that, in the relatively shower-free easterlies (average sea fetch 180 nautical miles), the variances of the errors in the present method are significantly smaller than those of Frost at the 5 per cent level, but the reduction of Blackall's variances by about one-third is not significant for a sample of only 30 trials. (If this apparent reduction in variance is true, however, the odds against obtaining a result which is significant at the 5 per cent level from 30 trials are 3 to 1.)

In the more showery northerlies (average sea fetch 230 nautical miles), there is little to choose between Blackall's method and the present method, though Blackall forecasts the coastal dew-points better. Frost's method shows large positive mean errors but with surprisingly small standard deviations. In these conditions none of the methods tested really achieved a satisfactory performance.

It is interesting that in Table II the mean errors in dew-point found by Grant's method are −2·0 degC for easterlies and −1·6 degC for northerlies. It would appear that Businger's formula tends to forecast inland rather than coastal dew-points.

Practical procedure

(a) *Forecast technique.* Use the technique to forecast surface air temperatures and dew-points at sea or at coastal stations (also inland when vertical heat- and water-vapour fluxes are small) in air with near-surface temperatures lower than the underlying sea surface temperature, when an upwind radiosonde ascent is available.

(b) *Sea fetch* (s). Decide on the trajectory and the representative speed V of the cold air. Write down the expected time of arrival of the air at your station (using V) and the length s of fetch over the sea in units of 1 nautical mile or 60 nautical miles ($\approx$1 degree of latitude).

(c) *Sea temperature* (T_S) *and saturation mixing ratio* (r_S). Write down the mean value of these as accurately as possible.

TABLE II—ERRORS OF THREE METHODS OF FORECASTING TEMPERATURE AND DEW-POINT IN COLD-AIR ADVECTION OVER THE SEA FROM 'ACTUAL' CHARTS (AFTER HEDGE[4])

	(a) Easterlies (30 trials)			(b) Northerlies (21 trials)		
TEMPERATURE						
Method	Frost	Blackall	Grant	Frost	Blackall	Grant
Mean error (degC)	0·7 ± 0·3*	0·4 ± 0·2	−0·2 ± 0·2	3·0 ± 0·4	1·5 ± 0·5	1·4 ± 0·4
'Student's' t	2·48	2·05	0·89	7·87	2·98	3·30
P	0·01	0·05	>0·10	0·01	0·01	0·01
Root-mean-square error (degC)	1·62	1·27	0·98	3·43	2·74	2·45
Standard deviation of error (degC)	1·5 ± 0·2	1·2 ± 0·1	1·0 ± 0·1	1·7 ± 0·3	2·3 ± 0·4	2·0 ± 0·3
Methods	Frost/Blackall	Frost/Grant	Blackall/Grant	Frost/Blackall	Frost/Grant	Blackall/Grant
F	1·54	2·30	1·49	1·84	1·38	1·30
P	>0·10	0·02	>0·10	0·10	>0·10	>0·10
DEW-POINT						
Method	Frost	Blackall	Grant	Frost	Blackall	Grant
Mean error (degC)	3·8 ± 0·4	1·0 ± 0·3	−2·0 ± 0·3	5·2 ± 0·4	0·3 ± 0·6	−1·6 ± 0·6
Root-mean-square error (degC)	4·32	2·09	2·53	5·55	2·46	3·08
Standard deviation of error (degC)	2·2 ± 0·3	1·9 ± 0·2	1·6 ± 0·2	1·9 ± 0·3	2·5 ± 0·4	2·7 ± 0·4
F	1·32	1·89	1·43	1·73	2·00	1·16
P	>0·10	0·05	>0·10	>0·10	0·07	>0·10

* The numbers after the ± signs are the standard errors of the numbers in front of them, with rounding to one place of decimals.

Notes:

(a) 'Student's' t here is the difference between the mean unrounded error and zero, divided by the standard error.
(b) F is the ratio of the larger of the squares of the standard deviation of error to the smaller, for each pair of methods.
(c) P is the significance level reached by the value of t or F.

(d) *Depth of convection* (d). On a tephigram showing the upwind station sounding draw the isobar of the mean sea-level pressure p_s along the trajectory. Draw a dry adiabatic from the mean sea surface temperature and pressure to meet the environment curve. Draw the isobar through this meeting point. Write down the depth of convection in millibars (see Figure 2).

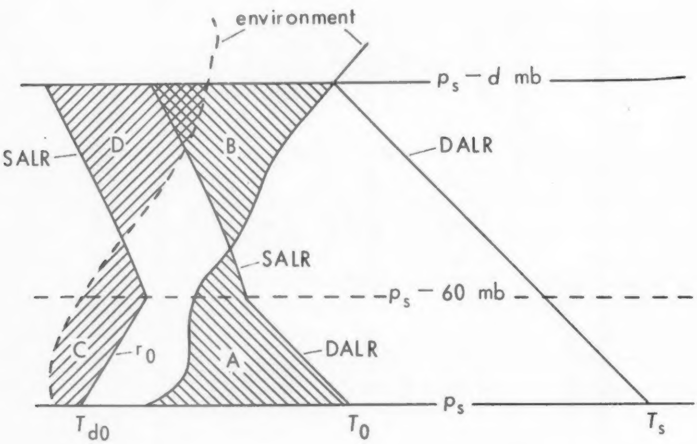


FIGURE 2—CONSTRUCTION FOR OBTAINING MODIFIED INITIAL SURFACE AIR TEMPERATURE (T_0) AND MODIFIED INITIAL MIXING RATIO (r_0)

A = B C < D
DALR = Dry adiabatic lapse rate
SALR = Saturated adiabatic lapse rate
See Appendix I for explanation of symbols.

(e) *Modified initial air temperature* (T_0). Draw the expected lifting condensation level (LCL) isobar at the end of the sea crossing. The best first guess at this is about 500 m or ($p_s - 60$) mb. If the upper-air station is inland, modify the lower part of the ascent to correspond to station reports on the coast at the time when the air crosses it as an offshore wind. Draw the path followed by a parcel of air condensing at the expected LCL so that equal areas are enclosed between the path curve, the environment curve, and the isobars $p_s - d$, as in Figure 2. The temperature at which this path curve intersects the surface isobars is the modified initial temperature T_0. Write down T_0 and $T_s - T_0$.
Note: It is necessary to modify the initial surface temperature (and mixing ratio) in a way such as this in order to obtain a value representative of the air following the vigorous mixing of the lower layers which occurs very soon after the air moves over the sea.

(f) *Modified initial mixing ratio* (r_0). Modify the dew-point curve by using a constant-mixing-ratio line up to the LCL and a saturated adiabatic above, so that the total water-vapour content between the isobars p_s and $p_s - d$ is unchanged. This is not easily done on a tephigram since the 'equal-areas'

rule does not apply, but with experience r_0 should be determinable to within 0·1 g kg^{-1} and is given by the modified mixing ratio below the LCL (Figure 2).

(g) *Final temperature* (T). Use the nomogram (Figure 3) to obtain the rise of surface air temperature ΔT and thence the final downwind temperature $T = T_0 + \Delta T$. Figure 3 is constructed for N equal to 1·40.

(h) *Final mixing ratio* (r), *dew-point* (T_d) *and lifting condensation level.* Read off Z to the nearest hundredth from the nomogram. The final mixing ratio is given by $r = r_0 + Z(r_s - r_0)$. Write down the corresponding surface dew-point T_d as determined from a tephigram. The final LCL is given approximately by $120 (T - T_d)$ metres or $400 (T - T_d)$ feet.

Notes: (1) When N (Table I) is much different from 1·40, the nomogram can still be used if s is multiplied by $N/1{\cdot}40$. This elaboration will rarely be necessary near the British Isles.

(2) If the sea temperature is very variable the procedure may have to be carried out on two or more segments serially.

(3) Slightly greater accuracy may be achieved by successive approximation, using the calculated LCL, but this will rarely be worth while.

Conclusions. The method presented in this paper for forecasting coastal temperatures in cold-air advection with onshore winds appears to perform rather better than Blackall's method, though giving no real improvement in showery northerlies. Businger's method for forecasting dew-points gives coastal values which are too low, often by about 2 degC, but it should be useful for forecasting dew-points some way inland.

Acknowledgements. The author would like to thank Mr R. M. Blackall, Meteorological Office College, for providing the data, and also Dr D. J. Carson and Dr F. B. Smith for their useful advice, and Mr C. L. Hawson for help in preparing this paper.

REFERENCES

1. BLACKALL, R. M.; Warming of the lower troposphere by the sea. *Met Mag, London,* **102**, 1973, pp. 65–73.
2. FLEAGLE, R. G. and BUSINGER, J. A.; An introduction to atmospheric physics. New York and London, Academic Press, 1963.
3. FROST, R.; The influence of the North Sea in winter on temperature and dew-point, 1941. (Unpublished, copy available in the Meteorological Office Library, Bracknell.)
4. HEDGE, SHEILA M.; Comparative trial of Blackall, Frost and Grant's methods of forecasting the modification of cold air over the sea. (Unpublished, copy available in the Meteorological Office Library, Bracknell.)

APPENDIX I—SYMBOLS

c_p	specific heat of dry air at constant pressure
C_E	water-vapour transfer coefficient
C_H	heat-transfer coefficient ($= H/c_p \rho V (T_s - T)$)
d	depth of convection over the sea (mb)
E	upward evaporative flux of water vapour above the sea
g	acceleration due to gravity
H	upward flux of sensible heat above the sea

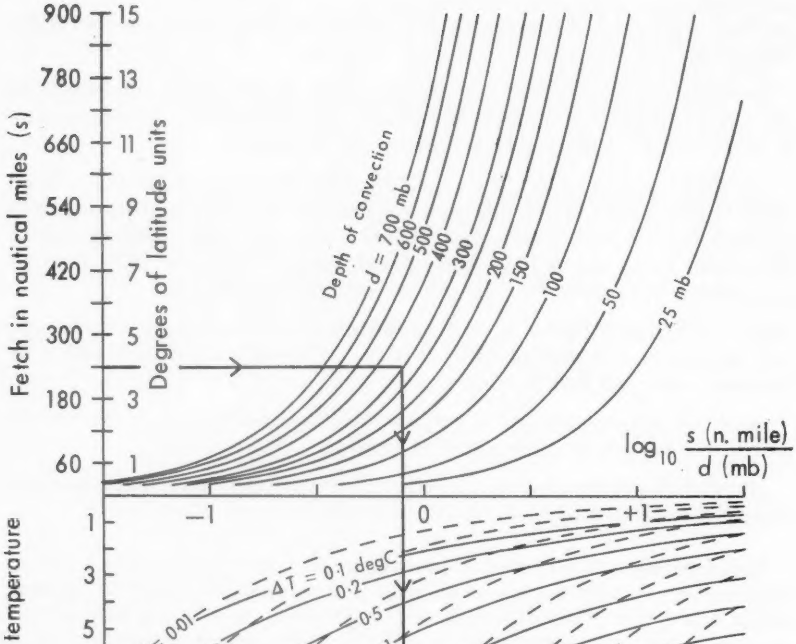


FIGURE 3—NOMOGRAM FOR DETERMINATION OF ΔT FROM s, d, AND $T_s - T_0$

Isopleths of ΔT ——

Isopleths of Z - - -

$T = T_0 + \Delta T$

$r = r_0 + Z\,(r_s - r_0)$

p_s mean sea-level pressure along trajectory
r humidity mixing ratio of air near surface
r_0 modified initial mixing ratio
r_s saturation mixing ratio at temperature T_s
R gas constant for air
s sea fetch; length of completed trajectory over sea
t time of sea crossing (s/V)
T surface air temperature at sea or on coast downwind of sea
T_0 modified initial surface air temperature
T_d dew-point of surface air at sea or near coast downwind of sea
T_s sea surface temperature
$\overline{T}$ average value of T along track
V average speed of cold air
Y $(T - T_0)/(T_s - T_0)$
Z $(r - r_0)/(r_s - r_0) = 1 + \frac{1 - Y}{Y} \ln (1 - Y)$ according to Businger[8]
α power of $(T_s - T)$ in expression for C_H
β dimensionless coefficient in expression for C_H
ρ air density near sea surface

551.507.362.2:551.576.2

AN IMPROVED SATELLITE NEPHANALYSIS

By R. HARRIS and E. C. BARRETT
(Department of Geography, University of Bristol)

Summary. Standard satellite nephanalyses have certain limitations which suggest that an improvement in the present procedure would be useful. From these limitations and a list of the requirements of a nephanalysis procedure, an improved satellite nephanalysis on three layers is derived which increases the information content to between three and five times that of the standard nephanalysis, provides a defined set of operational guidelines for the analyst, and allows for a wider range of forecasting and archival usages.

Introduction. Satellite visible imagery presents a rich array of weather information to the user. For many purposes a summary of this information is adequate, for example a snapshot summary for forecasting purposes, or accumulated totals and their dependent means for climatological purposes. Satellite nephanalyses represent a summary over space of the salient features of a cloud field, using a discriminant analysis-classificatory form to subdivide an area on the basis of its cloud characteristics (cloud type, percentage cloud cover, etc.).

Although several attempts have recently been made to produce objective nephanalyses by computer (Decotiis and Conlan,[1] and Shenk and Holub[2]), there appears to have been little change in the procedure for hand-drawn nephanalyses since the mid sixties (Godshall[3]). Despite minor variations,* the standard nephanalysis code employed in the United Kingdom Meteorological Office is that operated by the former U.S. Weather Bureau, and discussed more fully in Barrett.[4] This, in turn, is essentially an adaptation of the pre-satellite nephanalysis, defined as 'the study of synoptic charts on which only clouds and weather are plotted' (Berry *et alii*[5]), and issued to provide an input

* For example the anticyclone symbol (U.S. Weather Bureau) = the cold pool vortex symbol (U.K. Meteorological Office).

to the forecasting services. Observations plotted on the pre-satellite nephanalyses were as follows: cloud type, cloud amount, precipitation, weather, cloud ceilings and cloud-top heights. Of these, only the first two could be included in satellite nephanalyses, although areas *thought capable* of precipitation are outlined as 'synoptically significant'. Several other characteristics (e.g. size of features, jet-stream location, striations) have since been added.

Limitations of standard nephanalyses. Several authors have found that nephanalyses provide a useful data source for cloud studies, especially in conventional data-sparse regions. Such studies have been both direct, e.g. temporal cloud summaries (Sadler[6]), and indirect, e.g. the relative probabilities and intensities of rainfall (Barrett[7,8]). Even towards the end of the 1960s, nephanalyses provided 'the only source of global data from the weather satellites containing quantized cloud information' (Clapp[9]). The standard nephanalyses do, however, contain certain inadequacies, and some of the more pertinent ones may be outlined as follows:

(a) No rules governing the steps to be followed in constructing the nephanalysis have been established. This has resulted in a variation in nephanalysis procedures from country to country and from one analyst to another.

(b) Only four cloud-cover categories—'Open', 'Mostly Open', 'Mostly Closed' and 'Closed'—are recognized. Of these, two have ranges of 20 per cent and two have ranges of 30 per cent.

(c) 'Synoptically significant' cloud areas are outlined totally at the discretion of the analyst, without reference to any advisory guidelines.

(d) Cloud-type recognition is concentrated on a distinction between stratiform and cumuliform clouds. It is indisputable that cumulonimbus and cirrus are rarely identified as such in middle latitudes, whilst stratocumulus is under-represented on the charts in both low and middle latitudes.

(e) There is no established minimum-size reference giving guidance as to which cloud patterns to include in, and which to exclude from, the nephanalysis.

(f) Detail on variations of cloudiness at the 'meso' scale (e.g. squall-lines, convective-cloud patterns) is sparse.

(g) Conventional symbols are employed even though data from a new source and a new view are being considered.

Requirements of an improved nephanalysis procedure. Many of the criticisms that can be levelled against the standard nephanalysis arise because it is produced essentially as an aid to synoptic-scale forecasting. The general information content is consequently lower than the users of nephanalysis archives would like to see. In particular, it seems that any improved nephanalysis scheme should include more details of the cloud field at both the 'macro' and 'meso' scales, so that it will be of more general use rather than simply an aid to forecasting. This is particularly important in the developing countries where conventional observations are sparse, and in oceanic areas where there are relatively few island stations. In such areas more detailed nephanalyses could provide much information otherwise unavailable, for example for reasons of cost or inaccessibility.

Before we propose appropriate improvements to the practice of satellite nephanalysis a number of objectives may be identified. These include the following:

(a) The nephanalysis information content should be as accurate and as complete as possible, within stated constraints of scale.
(b) The chart must be clear and readily understandable, irrespective of the degree of detail that it contains.
(c) The satellite-image interpretation procedure should be standardized to minimize operator variance.
(d) The scheme should be capable of completion in operational circumstances within one hour.
(e) The system should be sufficiently flexible, (1) for use over areas of different size and (2) for application of the results to a range of secondary problems.

The improved nephanalysis scheme outlined below seeks to meet these requirements, visible images being used initially as the data base.

The improved nephanalysis. An increase in the amount of information portrayed on an improved nephanalysis raises the problem of clarity: how can the desired level of detail be achieved without forfeiting the simple, immediate visual impact of the standard nephanalysis? A first step towards solving this basic problem involves defining the type of analysis performed on the satellite imagery. This can take one of two forms: (a) a description of the cloud field, and (b) an interpretation of the cloud features present. If these procedures are separated, nephanalysis may be carried out more easily by distinguishing between the two methods employed. An example serves to illustrate the point. A roughly circular cloud feature of 6 degrees of latitude in diameter in the Indian Ocean, with more than 90 per cent of cloud cover (mainly cumulonimbus and cumulus congestus cloud types, and striations spiralling towards a central clear area), is a *description* of the appearance of a tropical storm from satellite altitudes. It is the *interpretation* of this cloud area which defines it as a hurricane.

We propose that description and interpretation of cloud fields be separated both in stage of execution and in mode of presentation. Since description is the easier task to undertake, we suggest further that a three-layered nephanalysis, comprising two descriptive layers and one interpretative layer, would be even better. This readily permits an increase of some 3–5 times in the information content compared with the standard nephanalysis. The format of this improved nephanalysis comprises:

(a) a base layer on opaque paper giving details of the geography and cloud cover,
(b) a transparent overlay carrying information on cloud type and cloud structure, and
(c) a second transparent overlay depicting an interpretation of features of the cloud field.

The stages to be followed in constructing this improved nephanalysis are summarized in Figure 1, and an example of its operation is given in Figure 2 (an improved nephanalysis derived from the ESSA 9 satellite imagery for 3 February 1970 shown in Plate I).

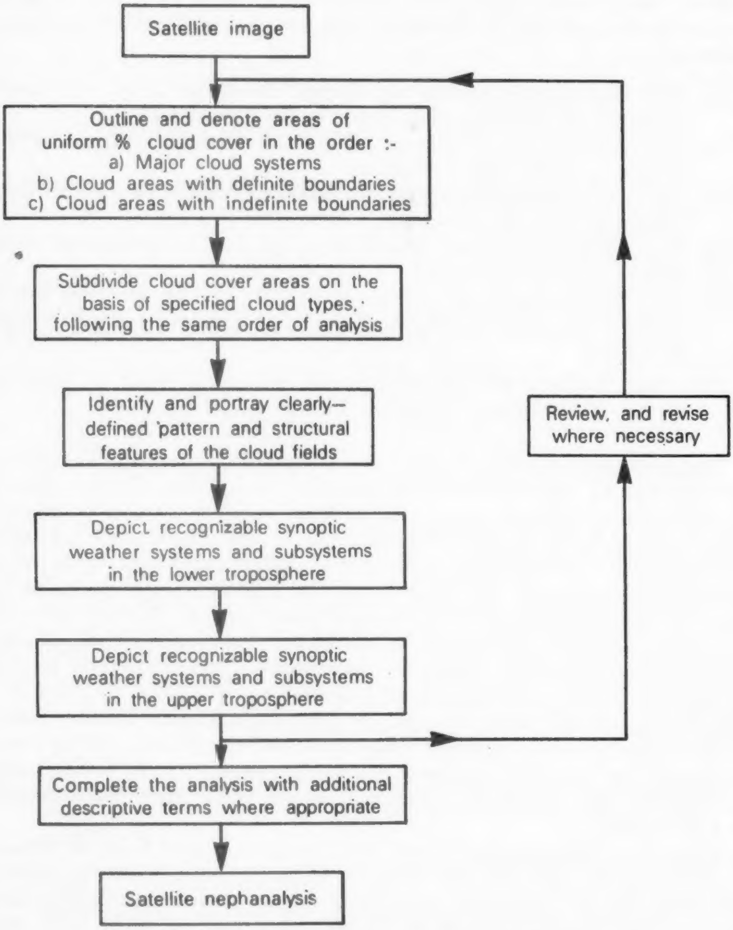


FIGURE 1—STAGES IN THE CONSTRUCTION OF AN IMPROVED SATELLITE NEPHANALYSIS

Description of the cloud field is the first method of analysis applied to the satellite photograph. The results comprise the lower two layers as follows:

(a) The spatial distribution of cloud cover is represented by an areal density shading on layer 1 (Figure 2a). For this purpose, five equal classes of percentage overcast are used (see Figure 2d). These five intervals replace the previous four, thereby providing more scope for detailed depiction of the cloud cover. An added advantage is that each class possesses the same range (i.e. 20 per cent). Areas of uniform cloud amount are outlined in the order suggested in Figure 1, firstly definite and secondly indefinite systems, both bordered by solid lines. The

suggested minimum-size constraint operates on the basis of an area equivalent to a $2\frac{1}{2}$-degree square, so no features larger than this should be omitted from the nephanalysis. All single linear features of more than 5 degrees of longitude or latitude in length should be included.

(b) Cloud type and cloud structure form the bases for the second set of descriptive characteristics, and are represented in symbolic form on the first of the transparent overlays (Figure 2b). Accurate recognition of cloud type is a major problem in nephanalysis so the standardization of recognition procedures is imperative. The scheme suggested by Anderson[10] of identifying clouds from their brightness and texture characteristics provides a set of operational guidelines suitable for such a standardization. Where cloud type varies within an area of the same cloud amount, dashed lines are used to depict this change rather than the solid-line boundaries used for cloud cover. The remaining descriptive features on the second layer are size of clouds and open spaces, and cloud pattern and shape. The symbols for these features are given in the key for the improved nephanalysis in Figure 2d.

(c) The interpretation of the cloud field is the final layer of the improved nephanalysis set (Figure 2c), and involves the identification of the features described in the lower two layers and other associated phenomena. In compiling the list of interpretation features shown in Figure 2d, information was drawn from the ESSA *Technical Report* entitled 'Application of meteorological satellite data in analysis and forecasting' (Anderson *et alii*[11]), which contains a comprehensive appraisal of the cloud features normally found on satellite visible imagery. One significant addition to the list is the identification of cloud-top height, which is determined from the brightness, cloud type and synoptic situation of a given area. The cloud-top height is then placed in one of three simple categories—high (above 6 km), middle (2–6 km) or low (below 2 km) (Berry *et alii*[5])—and portrayed appropriately (Figure 2d).

Any combination of these three layers can be used to give the required level of information for a particular *purpose*. For example, cloud cover (layer 1) and cloud type (layer 2) can be used for climatological applications (especially in weather bureaux where the forecasting programme is predominantly numerical), and all three layers for synoptic forecasting (especially where more traditional forecasting procedures are followed).

As the improved nephanalysis is a free-hand technique, the charts can be completed within one hour for 'real-time' operational use in synoptic forecasting. The optimum arrangement of the three charts at the central forecasting/automatic picture transmission facility is for flanking charts to be printed in reverse on transparent material, so that they can be folded in to overlay the others. For facsimile transmission to regional weather centres and other users the three charts could be transmitted side by side.

Standard and improved nephanalyses: a concluding note. The improved nephanalysis introduced in this paper is an attempt to fulfil the requirements of a nephanalysis procedure listed above by increasing the information content and standardizing the rules for the preparation of the nephanalysis. The sectionalized format of this new chart is the most significant contribution to the increase in the amount of information presented to the

(a)

(b)

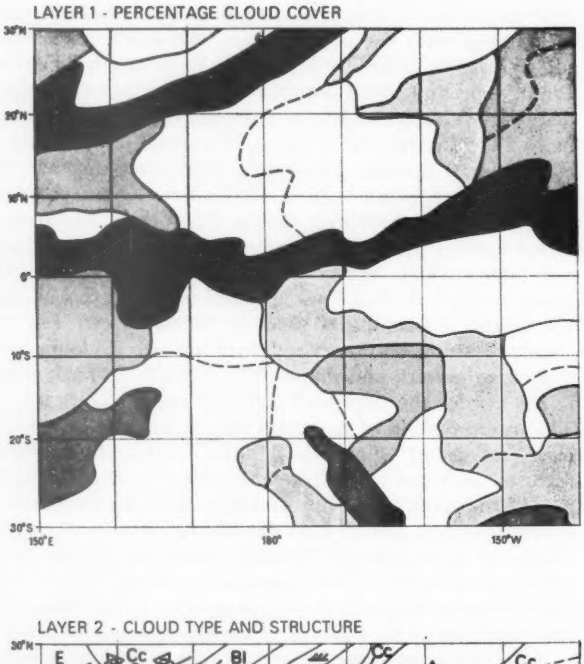
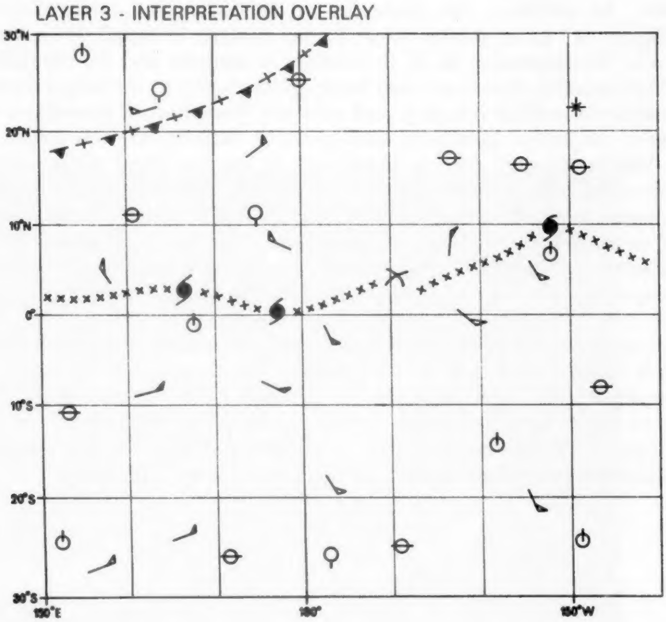


FIGURE 2—IMPROVED NEPHANALYSIS DRAWN FROM PLATE I

(a) cloud cover (b) cloud type and structure overlay

(c)



(d)

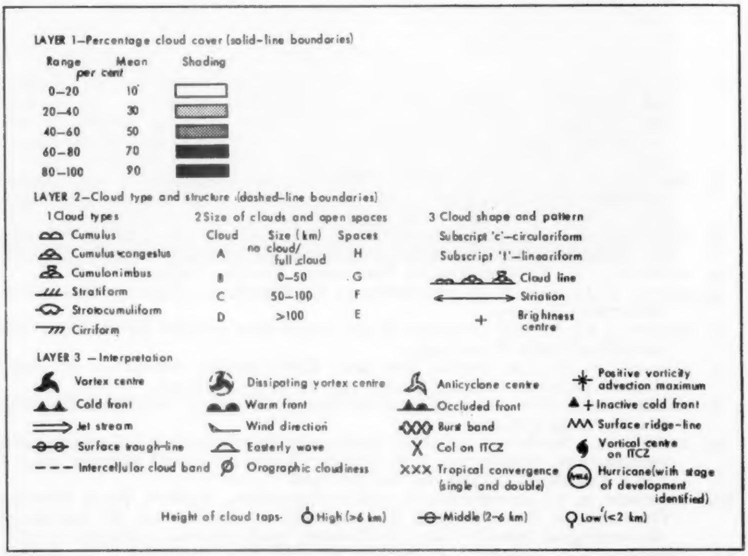


FIGURE 2—*continued*

(c) interpretation overlay (d) key to the improved nephanalysis scheme

user. In addition, the fuller list of descriptive and interpretative features (Figure 2d) gives greater scope for an analysis in detail down to the 'meso' scale. The separation of (a) the method of analysis, and (b) the different types of information shown on each layer, gives clarity to the stages followed in an analysis of satellite imagery, and with this flow-chart of procedures firmly laid down, subjective assessment and operator variance are minimized.

Visible imagery only is considered in the improved nephanalysis scheme presented here. However, an extension of the data sources to include infra-red imagery would be useful for increasing the information content and frequency of coverage provided by nephanalyses. Our work at Bristol University is directed now towards the development of a nephanalysis scheme for infra-red imagery. The biggest problem involves the diurnal temperature changes at the earth's surface and in the lowest layer of the atmosphere. The biggest advantage stems from the twice-daily reception of the images from the satellite. It is to be hoped that the analytical techniques which we are designing to be applied by cheap objective means may be applicable either to infra-red or to visible satellite images. Such developments must await the future, but it can be affirmed now that by using infra-red and visible imagery together, improvements in our analysis of satellite imagery will follow.

REFERENCES

1. DECOTIIS, A. G. and CONLAN, E. F.; Cloud in formation in three spatial dimensions using infrared thermal imagery and vertical temperature profile data. Proceedings of the Seventh International Symposium on Remote Sensing of the Environment. Center for Remote Sensing of the Environment, Ann Arbor, Michigan, 1971, 10259–1–X, pp. 595–606.
2. SHENK, W. E. and HOLUB, R. J.; A multispectral cloud type identification method using NIMBUS 3 MRIR measurements. Boston, Mass, Amer Met Soc, *Conf Atmos Radiat, Fort Collins, Col.*, 1972, *Boston*, 1972, pp. 152–154.
3. GODSHALL, F. A.; Intertropical convergence zone and mean cloud amount in the tropical Pacific Ocean. *Mon Weath Rev, Washington*, **96**, 1968, pp. 172–175.
4. BARRETT, E. C.; Viewing weather from space. London, Longmans, 1967.
5. BERRY, F. A., BOLLAY, E. and BEERS, N. R.; Handbook of meteorology. New York, McGraw-Hill, 1945.
6. SADLER, J. C.; Average cloudiness in the tropics from satellite observations. Honolulu, East–West Center Press, 1969.
7. BARRETT, E. C.; The tropical Far East: ESSA satellite evaluations of high season climatic patterns. *Geog J, London*, **137**, 1971, pp. 535–555.
8. BARRETT, E. C.; Forecasting daily rainfall from satellite data. *Mon Weath Rev, Washington*, **101**, 1973, pp. 215–222.
9. CLAPP, P. F.; Northern hemisphere cloud cover for selected late fall seasons using TIROS nephanalyses, Washington, U.S. Weather Bureau, National Meteorological Center, *ESSA Tech Memo, Washington*, No. 44, 1968.
10. ANDERSON, R. K.; Introduction to data interpretation. Geneva, World Meteorological Organization, Proceedings of the Inter-regional Seminar on the Interpretation of Meteorological Satellite Data, Melbourne, 1968, Geneva, 1969, pp. 15–17.
11. ANDERSON, R. K., ASHMAN, J. P., BITTNER, F., FARR, G. R., FERGUSON, E. W., OLIVER, V. J. and SMITH, A. H.; Application of meteorological satellite data in analysis and forecasting. Washington, D.C., U.S. Department of Commerce, ESSA Technical Report NESC 51, 1969.

To face page 16

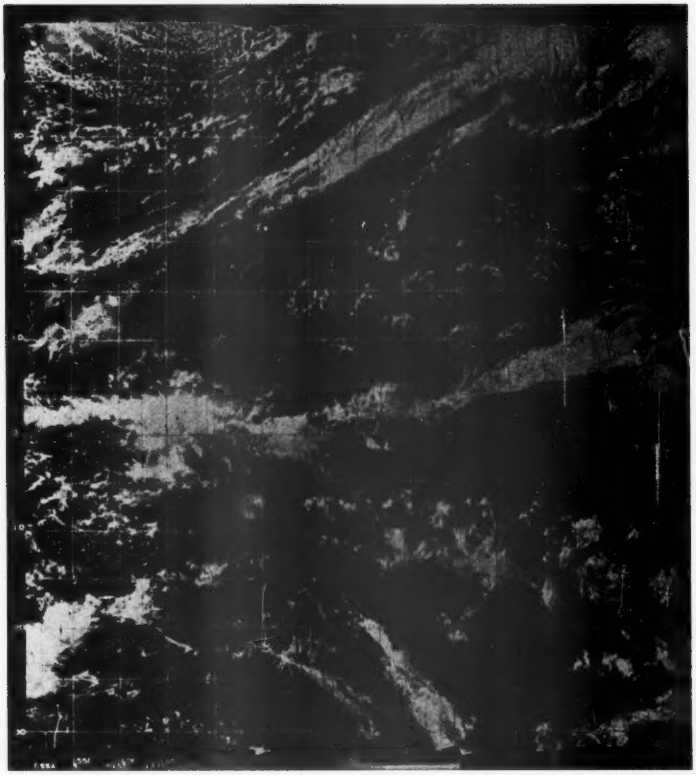


PLATE I—ESSA 9 COMPUTER-RECTIFIED MERCATOR MONTAGE OF THE CENTRAL PACIFIC, 3 FEBRUARY 1970

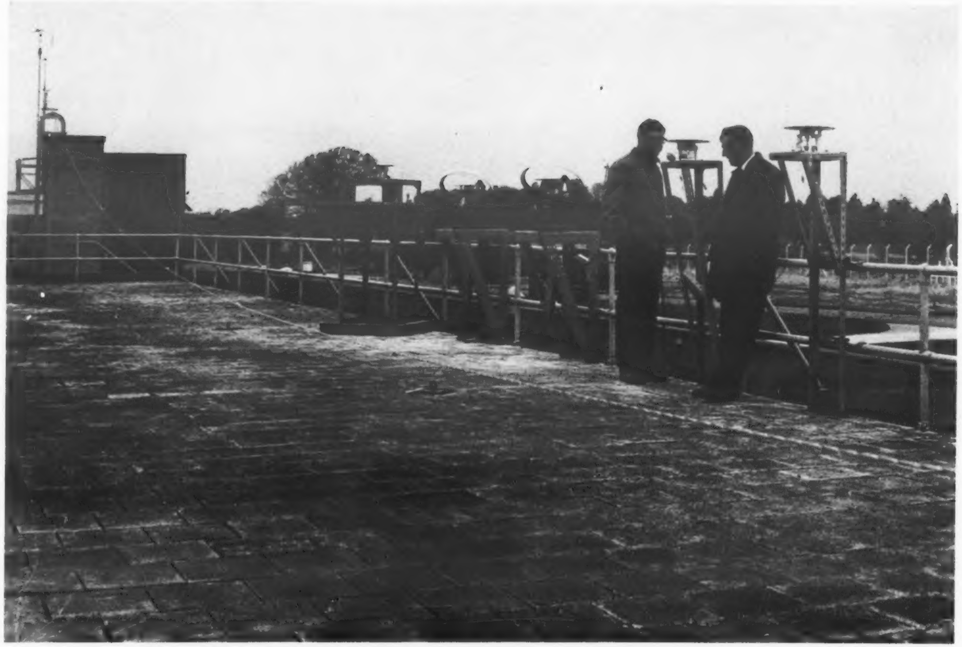


PLATE II—METEOROLOGICAL OFFICE EXPERIMENTAL SITE, BEAUFORT PARK, NEAR BRACKNELL

General view showing the exposure of radiation instruments on the roof of the main building.

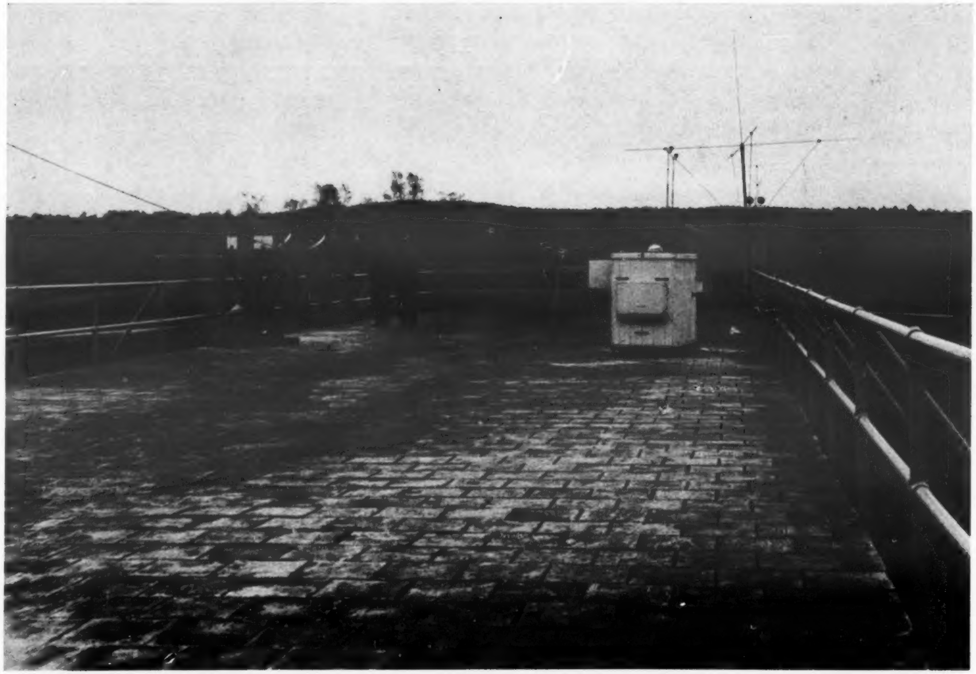


PLATE III—METEOROLOGICAL OFFICE EXPERIMENTAL SITE, BEAUFORT PARK, NEAR BRACKNELL
Another view of the radiation instruments on the roof of the main building.

To face page 17

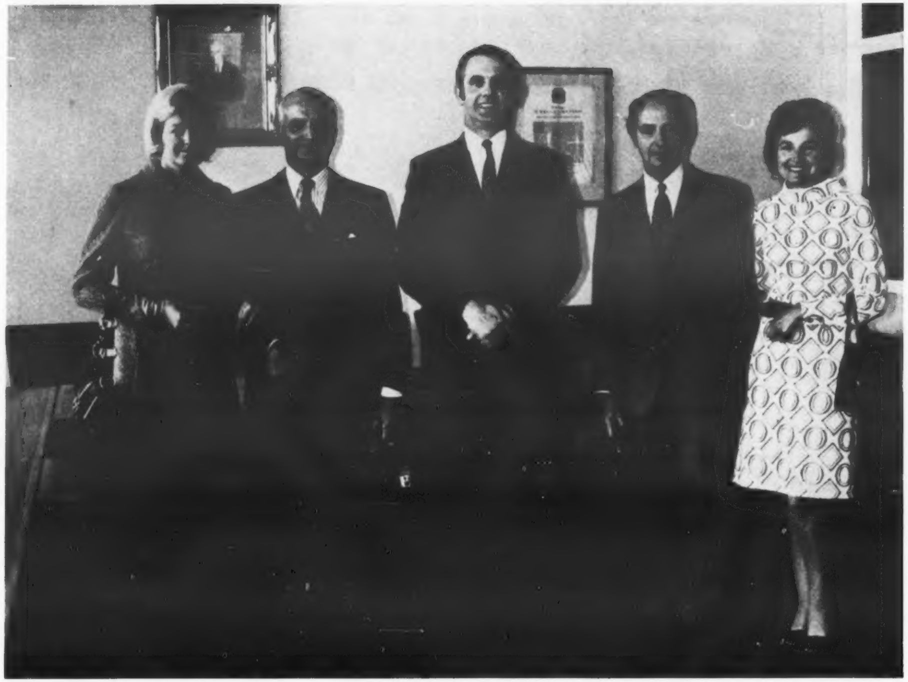


PLATE IV—AWARDS TO CIVIL AIRLINE PILOTS

From left to right: Mrs D. H. F. Banton, Captain D. H. F. Banton, Director-General of the Meteorological Office, Captain and Mrs K. Mountney (see page 28).

551.509.324.2

FORECASTING CONVECTIVE THUNDERSTORMS, HAIL AND SHOWER ACTIVITY IN THE MIDLANDS

By N. J. ATKINS

Summary. The parcel method, found to be widely used by forecasters because of its success compared with other techniques, was used in an investigation of convective activity in the Midlands. It is shown that, in addition to the depth of the convective layer, the amount of potential energy in the lower part of the layer shown on a tephigram can be used to determine the intensity of shower activity. An extension to the parcel method is therefore suggested in this paper.

Introduction. The Saunders[1] test of thunderstorm forecasting showed that 'general practice' gave better results than other techniques, and it was possible with help from several forecasters to determine what the 'general practice' was. Of the 26 forecasters who completed a questionnaire, 24 used the parcel method, and 10 of them used it in conjunction with another technique, which for seven of them included the slice method. Fourteen forecasters examined the size and shape of the positive area as given by the parcel method, but their reasons for doing this were too varied to be classified. It was decided therefore to analyse the relationship between weather reported and the data obtained from the parcel method, including the size and shape of the positive area shown on a tephigram. The completed questionnaire also showed that none of the 26 forecasters eliminated thunderstorms from a forecast because of the possible entrainment of dry air from the environment, but that the degree of such entrainment was used to judge whether convective activity would be widespread, scattered or isolated. During the present investigation, the water-vapour content of the two layers, 1000 to 700 mb and 1000 to 850 mb were analysed, and also the dew-point separation for the same two layers, but no useful result was obtained.

Period and area of the investigation. Five observing stations in the Midlands, namely Cardington, Wittering, Shawbury, Watnall and Elmdon (see Figure 1) grouped together in the *Daily Weather Report* were used for the four-year period from 1970 to 1973 inclusive. There are no radiosonde stations in the Midlands but normally the ascent from one or more of the nearest four stations (also shown in Figure 1) provided a representative temperature sounding.

Shape and size of the positive area (E). A quick method was required to assess the shape and size of the positive area as given by the parcel method using the forecast maximum temperature and the forecast dew-point at the time of this maximum temperature. It was found that the areas could be represented by the sum of the separations of the parcel and environment curves taken at 50-mb intervals, and that it was quicker to measure them with a scale of millimetres than to express them in degrees read from the tephigram. Measurements were made on Metform 2810, and it would be necessary to make a conversion if a differently scaled tephigram were used. (The scale of

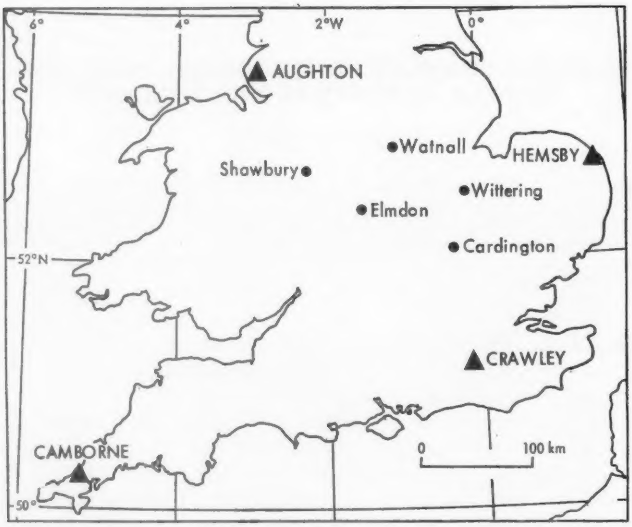


FIGURE 1—MAP SHOWING THE LOCATION OF THE FIVE REPORTING STATIONS IN THE MIDLANDS USED IN THE INVESTIGATION OF SHOWERS AND THUNDERSTORMS
The positions of the nearest four radiosonde stations (▲) are also shown.

Metform 2810 used is 10 degC = 52 mm and the energy equivalent is $9{\cdot}4 \times 10^{-2}$ J cm^{-2}.) The area was classified into one of three types:

(a) with a low centre of gravity,
(b) with a high centre of gravity, or
(c) with a central centre of gravity.

The positive area was divided into a lower part (E_L) and a higher part (E_H), and the classifications were made by comparing the areas. The level at which the area was divided was defined as the arithmetic mean of the surface pressure and the pressure where the parcel cut the environment curve. A measure of the degree of elongation of the positive area was made by linking it with the depth of instability at the saturated adiabatic lapse rate (SALR). Hamilton[2] has shown that the depth of instability at the SALR is a useful guide to shower activity.

Weather distribution diagrams. The weather reported at five Midland stations was related on distribution diagrams to the depth of instability at the SALR, to the size of the positive area, and to the size of the partial areas E_L and E_H. These were obtained from the most representative midday temperature sounding. The weather reported was taken from the five stations as a whole so that hail at one station and a thunderstorm with rain at another was classified as a thunderstorm with hail. Occurrences of snow were included as rain, and different symbols were allocated to the following weather classifications: (a) nil or slight shower, (b) moderate shower, (c) heavy shower,

(d) moderate hail shower, (e) heavy hail shower, (f) thunderstorm with rain, (g) thunderstorm with hail, and (h) thunderstorm with heavy hail. It was necessary to include every convection day during the four-year period and for the purpose of this work a convection day is defined as one on which convection would be expected to rise above 900 mb—there were 693 such days. All three diagrams showed an increase of shower intensity with increasing depth of instability at the SALR. There was also a trend for shower intensity to increase with increasing positive area, E, but this was most noticeable in the diagram which used E_L, the lower part of the positive area. This showed that at a constant depth of instability the intensity of weather reported was to a large extent proportional to E_L. Even so it was difficult to draw boundary lines on the diagram owing to the occurrence of several polar-air thunderstorms with relatively shallow instability depths. The diagram was therefore split into two, thereby separating the 'cold' days when the height of the 0°C isotherm was below 850 mb from the 'warm' days when the 0°C isotherm was at or above 850 mb; these two diagrams are illustrated in Figures 2 and 3. For the sake of clarity, occasions of nil or slight showers have been omitted from the diagrams—there were 411 such occasions. If they had been plotted they would mostly have occurred towards the origin of the diagram.

Hail. It is probable that hail reached the ground in places in the Midlands other than the five stations used in the investigation on most days when thunderstorms with rain only were reported. The chance of hail falling at one particular place, however, increases with the lowering of the 0°C isotherm and also with increasing E_L. This is shown in Figure 4 which used all convection days when the depth of instability at the SALR was 200 mb or more with the occasions of nil or slight showers again being omitted.

Conclusions. Consideration of the models of hailstorm clouds as illustrated on page 159 of Ludlam,[3] and in Hitschfeld,[4] led to the working hypothesis that the strength of the updraught in the lower part, which must exceed a critical value to accelerate the hailstones upward sufficiently to carry them into the higher part, was likely to be more important and critical than that in the higher part. Hence the positive area given by the parcel method on a tephigram was able to provide additional information by virtue of the size of its lower portion and shape.

Method. (See example in Figure 5.)

(a) On a representative temperature sounding, modified for midday, use the non-superadiabatic maximum temperature and dew-point at the time of this maximum temperature, and draw in the parcel path from the surface pressure (P_1) up to the point where the parcel and environment curves meet (P_3).

(b) Mark in the mid point of the convection layer obtained by putting $P_2 = \frac{1}{2}(P_1 + P_3)$.

(c) Starting at 950 mb measure in millimetres the separation between the parcel and environment curves at every 50-mb interval up to P_2. If P_2 falls within ± 10 mb of a 50-mb multiple, then the measurement at the latter level is halved and included in the total to obtain E_L.

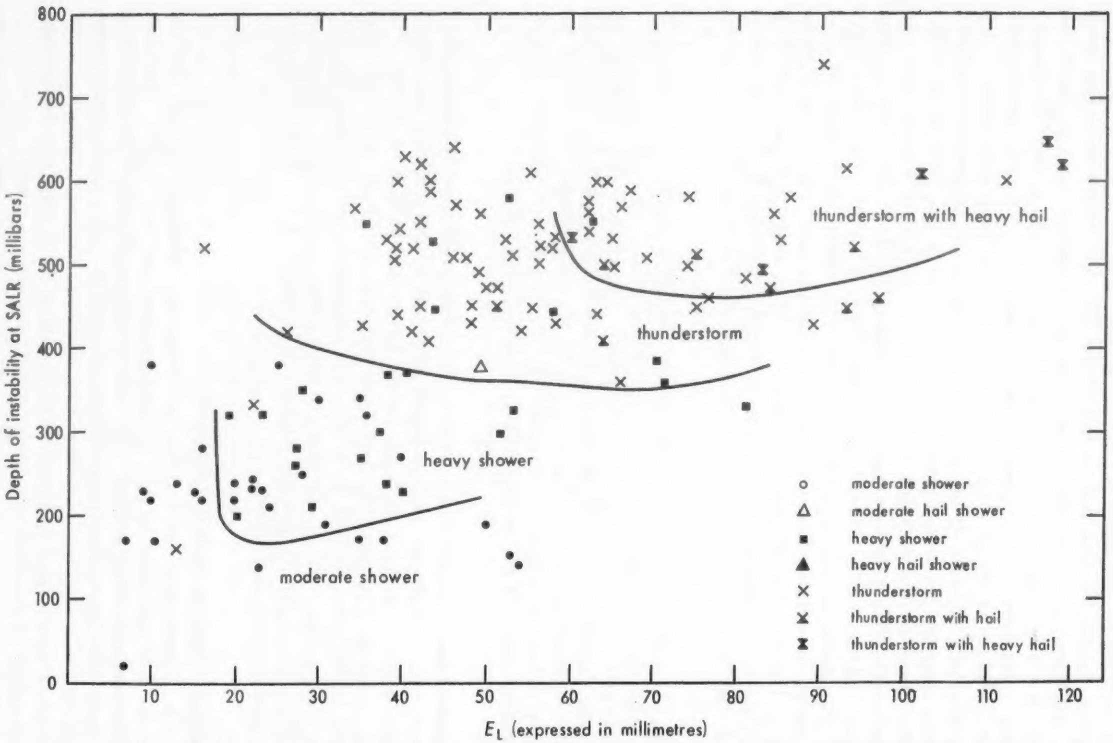


FIGURE 2—OCCURRENCES OF MODERATE AND HEAVY SHOWERS, HAIL AND THUNDERSTORMS ON CONVECTION DAYS WHEN THE 0°C ISOTHERM WAS AT OR ABOVE 850 mb FOR 1970–73 INCLUSIVE

The symbol for 'moderate shower' in the key should be ●

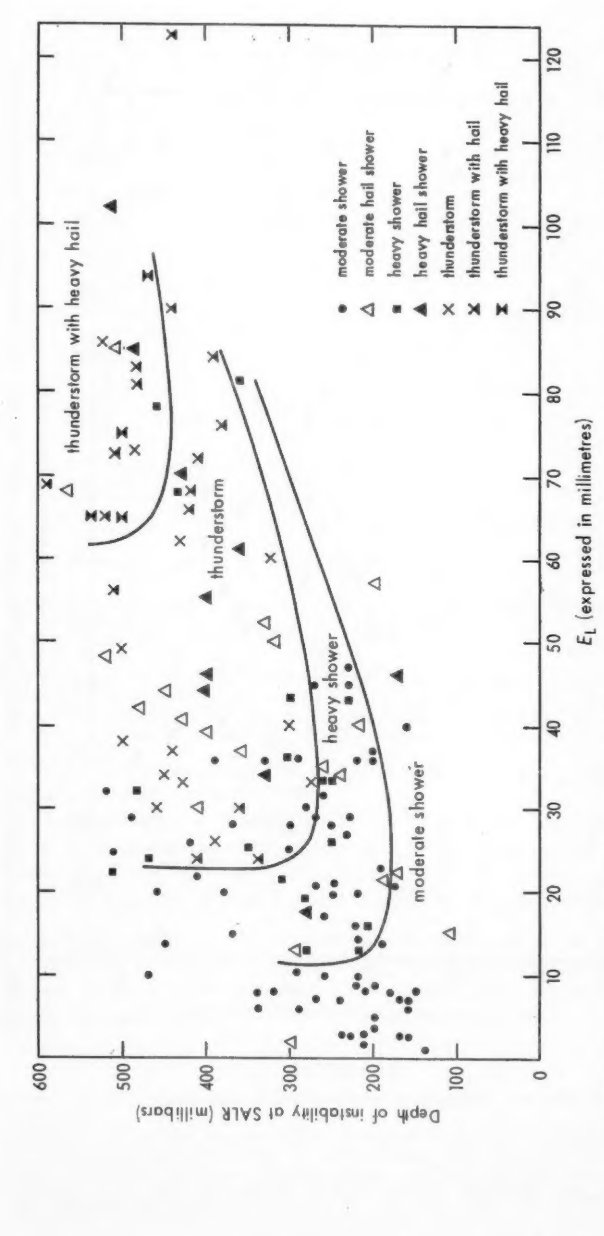


FIGURE 3—OCCURRENCES OF MODERATE AND HEAVY SHOWERS, HAIL AND THUNDERSTORMS ON CONVECTION DAYS WHEN THE 0°C ISOTHERM WAS BELOW 850 mb FOR 1970–73 INCLUSIVE

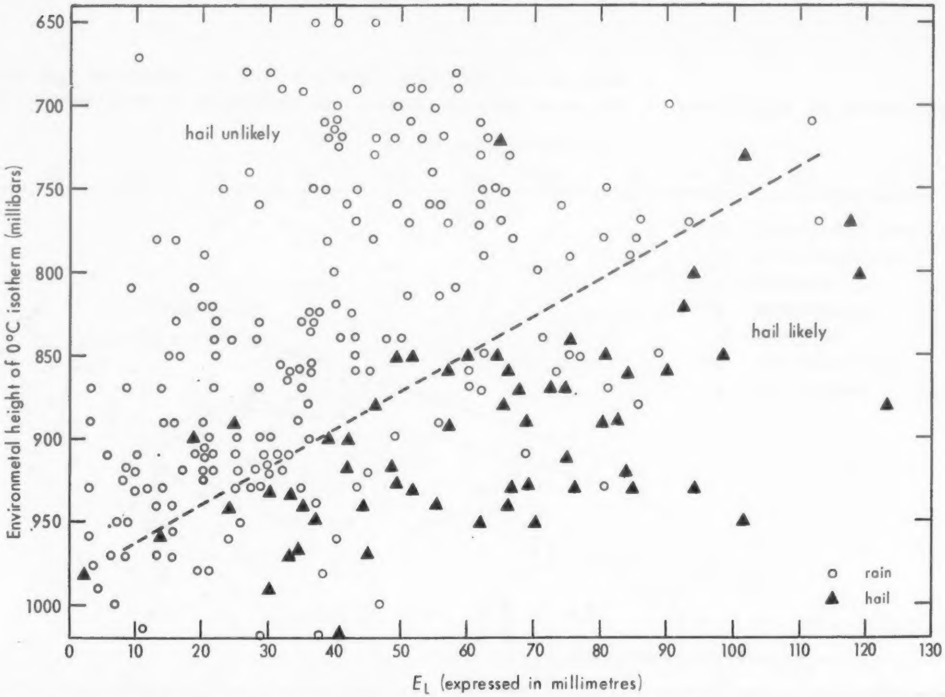


FIGURE 4—OCCURRENCES OF MODERATE AND HEAVY RAIN OR HAIL ON CONVECTION DAYS WHEN THE INSTABILITY DEPTH AT THE SATURATED ADIABATIC LAPSE RATE WAS EQUAL TO OR GREATER THAN 200 mb FOR 1970–73 INCLUSIVE

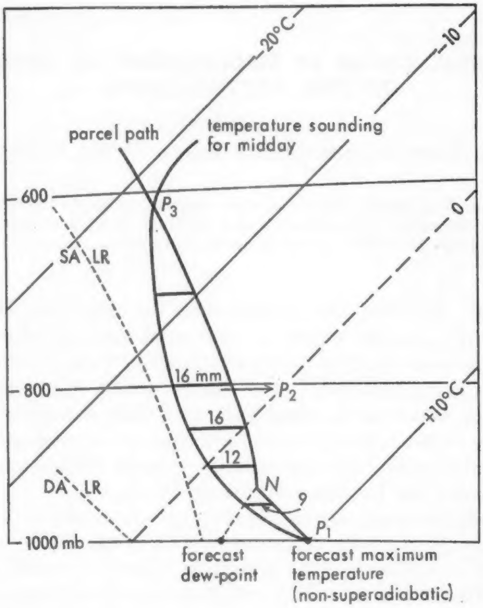


FIGURE 5—AN EXAMPLE OF THE SUGGESTED EXTENSION TO THE PARCEL METHOD

P_2 (805 mb) is the arithmetic mean of the surface pressure P_1 (1000 mb) and the pressure where the path curve for the parcel cuts the environment curve at P_3 (610 mb).
E_L is the sum of the measured separations at 50-mb intervals between the two curves from 950 mb up to P_2.
If P_2 falls within $\pm$ 10 mb of a 50-mb multiple, the measurement is halved and included in the total. In this example (a) $E_L = (16/2) + 16 + 12 + 9 = 45$ mm, (b) the instability depth at the SALR is 930(N) − 610 = 320 mb and (c) the height of the 0°C isotherm is 895 mb. From Figures 2 and 4 of this article, thunderstorms with hail would be forecast.

(d) Obtain depth of instability at the SALR, i.e. $N - P_3$ mb (N is the condensation level).

(e) Use values from (c) and (d) above to find the expected convection weather from either Figure 2 or Figure 3, depending on the height of the environmental 0°C isotherm. An indication of the chance of hail will be given by E_L and the height of the 0°C isotherm by using Figure 4.

Acknowledgement. The writer wishes to thank those forecasters at London Weather Centre, Watnall, Bawtry, Scampton, Wyton, Marham, and Cottesmore, who kindly completed the questionnaire on their method of forecasting thunderstorms.

REFERENCES

1. SAUNDERS, W. E.; Further tests of thunderstorm techniques. *Met Mag, London*, **96**, 1967, pp. 85–89.
2. (HAMILTON, P. M.); The frequency and intensity of showers in southern England in relation to upper air soundings. *Met Mag, London*, **88**, 1959, pp. 135–137.
3. LUDLAM, F. H.; The hailstorm. *Weather, London*, **16**, 1961, pp. 152–162.
4. HITSCHFELD, W. K.; Hail research at McGill 1956–71. *Scient Rep, McGill Univ Montreal, Montreal*, MW 68, 1971.

551.589.1(492):519.2

A BIENNIAL CYCLE IN THE NUMBER OF FINE DAYS IN THE NETHERLANDS

By C. J. E. SCHUURMANS
(Koninklijk Nederlands Meteorologisch Instituut, De Bilt, The Netherlands)

Summary. A statistical study is made of daily weather types at De Bilt over the period 1881–1972 which demonstrates the existence of a biennial cycle in the occurrence of warm, dry, and sunny weather from late spring to early autumn.

Introduction. In 1967 Davis[1] published an article on the summers of north-west Europe. In this article he presented some good evidence of the existence of a biennial cycle in north-western European summers—summers of the odd years being generally better than summers of the even years. The study was mainly based on seasonal means of daily maximum temperatures for seven stations in the British Isles and some 30 continental stations including De Bilt, The Netherlands. The temperature records studied varied from 30 to 90 years, the record for De Bilt comprising 65 years.

In Davis's study, for each station χ^2-values are computed for the contingency tables, giving the frequencies of summers with mean daily maximum temperatures higher or lower than the preceding summer for odd and even years separately. In Figure 1 of the article which is reproduced here, these χ^2-values are plotted and analysed according to the significance level. From this figure it is concluded that the biennial cycle is best developed over the British Isles, southern Scandinavia and large parts of France, western Germany and Austria. The χ^2-value for De Bilt by no means reaches the 5 per cent level of significance, which led the author to draw an isopleth of $\chi^2 = 3{\cdot}84$ (5 per cent level of significance) around the southern North Sea and its bordering areas thus creating an isolated region for which the biennial cycle is not in evidence.

The present paper presents the result of a statistical study of daily weather types at De Bilt over the period 1881–1972. It is shown that the biennial cycle of summer weather is also in evidence at De Bilt.

Weather types. Weather types have been defined in such a way that daily mean temperature, amount of precipitation and duration of sunshine determine the weather of a given day at a given place.

The frequency distribution of daily mean temperature for a certain day over 90 years has been subdivided into terciles. The lowest tercile is called 'below' (B), the middle 'normal' (N) and the highest 'above' (A). Daily precipitation amounts and relative duration of sunshine (per cent) have also been subdivided into three classes, but with fixed class limits, namely for precipitation: dry (D) is less than 0·3 mm, moderate (M) is 0·3–4·9 mm and heavy (H) is 5·0 mm or more; for sunshine: 25 per cent or less is cloudy (C), 26–49 per cent is partial (P) and 50 per cent or more is sunny (S).

Combinations of (B,N,A), (D,M,H) and (C,P,S) define 27 weather types. The frequency of occurrence of the various types varies from very frequent (some 15 to 20 per cent of all days in a certain season) to very rare (less than 1 per cent). Most of the types show a rather large annual variation.

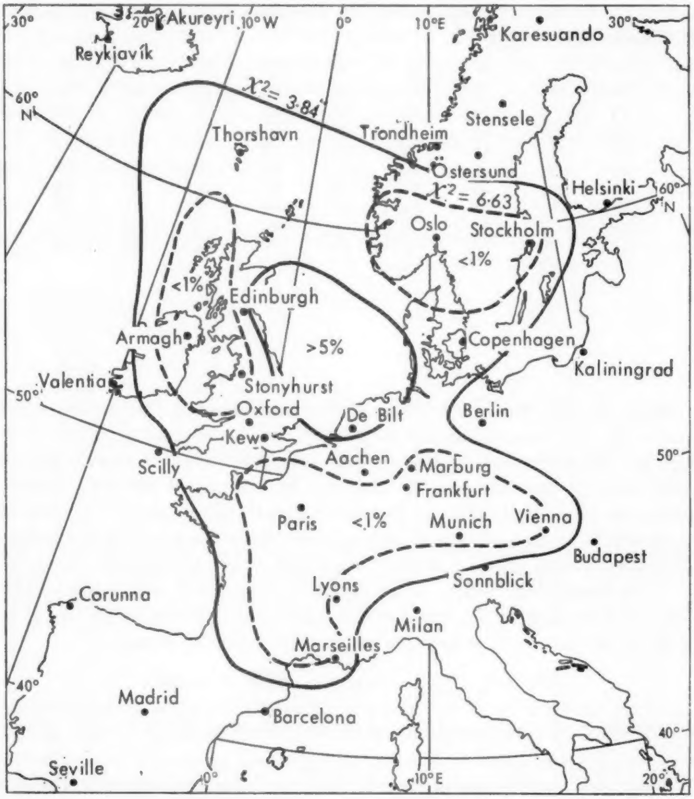


FIGURE 1—APPROXIMATE ISOPLETHS OF 1 PER CENT AND 5 PER CENT LEVELS OF SIGNIFICANCE OF χ^2

(After Davis;[1] see text.)

Weather types have been determined for De Bilt for each day from 1 January 1881 onwards.[2] We shall only consider here the weather type ADS—warm, dry and sunny weather.

Fine days in summer. The number of fine days (ADS-days) in summer June, July and August) at De Bilt shows a rather large interannual variation. For the period 1881–1972 these numbers are given in Table I. The number of ADS-days varies from 1 (in 1907, 1918 and 1962) to 51 (in 1947).

The values in Table I have been added for odd and even years separately. It turned out that the summers of the odd years had on the average about 4 (or 27 per cent) more ADS-days than the summers of the even years.

Statistical significance. Various statistical tests have been applied in order to investigate the statistical significance of the phenomenon.

TABLE I—THE NUMBER OF ADS-DAYS IN SUMMER (JUNE, JULY, AUGUST) FOR THE PERIOD 1881–1972

	0	1	2	3	4	5	6	7	8	9
188–	—	21	8	17	31	16	20	25	10	26
189–	15	9	11	24	10	20	23	23	12	29
190–	24	26	17	6	20	18	17	1	14	7
191–	12	30	15	9	27	7	9	16	1	17
192–	10	26	5	18	11	19	12	9	11	16
193–	19	9	29	31	25	28	19	20	14	23
194–	18	24	20	15	16	19	9	51	18	21
195–	20	9	14	16	5	22	3	16	12	30
196–	11	11	1	12	20	9	12	16	15	23
197–	24	18	7							

According to 'Student's' *t*-test the difference between the mean values for odd and even years is significant at nearly the 1 per cent level ($t = 2{\cdot}39$). On applying the parameter-free rank-sum test, which is more widely applicable than the *t*-test, it was also found that the hypothesis of the two samples of odd and even years belonging to the same distribution can be rejected at the 3 per cent level. In the latter test the years are ranked according to the number of ADS-days. When equal numbers occurred, those years have been ranked simply in chronological order. This procedure does not affect the validity of the test. The rank-sum T_0 for the odd years turned out to be 2417, which means that for the even years this sum (T_e) must be equal to

$$(N(N + 1)/2) - 2417 = 1861 \ (N = 92).$$

The expected T (μ_T) and its standard deviation (σ_T) are given by $\mu_T = \dfrac{N_1(N_1 + N_2 + 1)}{2}$ and $\sigma_T^2 = \dfrac{N_1 N_2 (N_1 + N_2 + 1)}{12}$, where in the present case $N_1 = N_2 = 46$.

For $N_1, N_2 > 10$, T is normally distributed.

By comparison with the standard normal distribution it is found that with $T = 2417$ the area under the standard normal curve between 0 and

$$z = \frac{2417 - \mu_T}{\sigma_T} = 2{\cdot}17$$

is 0·4850, from which we may conclude that the difference between T_0 (or T_e) and μ_T is significant at the $1 - 2(0{\cdot}4850) = 0{\cdot}03$, or 3 per cent level.

Though Davis from his analysis of mean maximum temperatures could not find the biennial cycle to be in evidence at De Bilt, our analysis clearly shows that, for the indicated period, differences between summers of odd and even years did exist. A preliminary conclusion could furthermore be that Davis's study had its limitations as to the demarcation of areas influenced by the biennial cycle.*

---

* Davis's method of analysis has also been criticized on statistical grounds by P. B. Wright (*Met Mag, London*, **100**, 1971, pp. 301–303).

Fine days over the year. As will be clear from the definition, fine days do occur mainly in summer. In the colder seasons of course DS (dry and sunny) more often goes with low (B) or normal (N) temperatures. Nevertheless, the numbers of ADS in spring and autumn are still large enough to analyse them for a possible extension of the biennial cycle into these seasons.

Table II gives for each month of the year the number of ADS-days for even and odd years separately.

TABLE II—THE NUMBER OF ADS-DAYS IN EACH MONTH FOR THE PERIOD 1881–1972

	Odd years	Even years	Difference
January	22	26	− 4
February	42	34	+ 8
March	114	132	−18
April	192	184	+ 8
May	278	243	+35
June	280	244	+36
July	312	221	+91
August	266	211	+55
September	205	153	+52
October	94	79	+15
November	33	24	+ 9
December	8	17	− 9

It turns out that in the autumn, especially in September, the biennial cycle is still influencing the number of fine days. As far as spring is concerned the effect seems only to be present in May.

Synoptic-climatological considerations. It is of interest to compare these results with conclusions which can be drawn from the monthly patterns of the quasi-biennial pressure oscillation, published by Murray and Moffitt.[3] From these patterns one may infer that from May to September anomalous high pressure occurs in odd years, as compared with the even years, over western to north-western Europe. This will cause in the season concerned more anticyclonic conditions over The Netherlands, accompanied by rather light winds varying in direction between north-east to east, and south. These circumstances easily explain the excessive occurrence of fine days.

In early spring and also in late autumn the pressure-difference patterns over Europe (still according to Murray and Moffitt) are quite different from those of the summer months. In general they are of such a nature that they would not favour more ADS-days to occur in odd years than in even years. When nevertheless, the figures in Table II suggest that the biennial effect is extended into late autumn, this could possibly be attributed to the fact that after good summers the North Sea is warmer than after less-good summers.

REFERENCES

1. DAVIS, N. E.; The summers of north-west Europe. *Met Mag, London*, **96**, 1967, pp. 178–187.
2. SCHUURMANS, C. J. E. and KRIJNEN, H. J.; Weertypeklimatologie voor De Bilt, 1881–1970. *Wet Rapp K Ned Met Inst, De Bilt*, WR 71–6, 1971.
3. MURRAY, R. and MOFFITT, B. J.; Monthly patterns of the quasi-biennial pressure oscillation. *Weather, London*, **24**, 1969, pp. 382–389.

REVIEW

Analytical methods in planetary boundary-layer modelling, by R. A. Brown. 200 mm × 140 mm, pp. xii + 148, *illus.*, Adam Hilger Ltd, Warner House, Folkestone, Kent, 1974. Price: £8.00.

This book cannot be recommended except perhaps as a means of gaining a general impression of current ideas on the origin and effect of vortex rolls in the boundary layer which arise from a vorticity and thermal instability of the quasi-Ekman layer velocity profile. These rolls occur quite frequently and can be important in determining the exact nature of the internal structure of the layer. The final third of the book is concerned with these instabilities, whilst the first two-thirds are devoted to a more general description of boundary-layer methods but with an eye very much on the needs of the final part.

The approach is a rather mathematical one, but the value of this is largely lost by a profusion of errors, some typographical, others more basic. For example on page 47 there are four errors in the space of four equations and one confusing bit of notation; on page 39, the basic equation, equation (4.3), is apparently hopelessly incorrect, and so on.

Even the physical concepts and arguments are often unacceptable. Section 5.2 on the surface layer is completely misleading; it implies that it is a *constant flux* layer (the fluxes actually fall off faster there than anywhere else in the boundary layer) and wrongly that its depth is comparable with the depth of the roughness elements z_0 (where the basic equations are in fact quite inadequate and therefore cannot be applied). The description of the physical reasons for the existence of vortex instability in the boundary layer—potentially the most interesting section of the book—is no help at all to the uninitiated and no source of admiration for those who do understand already.

The front cover is very attractive (showing a jet-stream cloud stretching across Egypt and Saudi Arabia (*not* Jordan!)). However, the reader has to search rather carefully to find those aspects relevant to the subject matter and the casual 'shopper' might be quite misled as to what this book is really about.

F. B. SMITH

NOTES AND NEWS

Meteorological Office awards to captains and navigators of civil airlines

Since 1954 awards have been made annually to encourage civil airline captains and navigators to make air reports. Suitably inscribed books are awarded to the captains and navigators who have provided the best series of reports during the year under review. Captains who have given long and meritorious service in the provision of air reports are considered for the award of brief-cases.

In 1974 brief-cases were awarded to Captain D. H. F. Banton, British Airways (Overseas Division), and to Captain K. Mountney, British Airways (European Division) by the Director-General at a ceremony held in the Headquarters of the Meteorological Office on 2 October (see Plate IV).

COVOS/COMESA Conference

A successful joint conference was held in Oxford on 24–26 September 1974 by the French COVOS (Comité sur les Conséquences des Vols Stratosphériques) and the British COMESA (Committee on the Meteorological Effects of Stratospheric Aircraft) groups which have been studying the possible environmental effects that might arise from the operation of large numbers of supersonic transport aircraft in the stratosphere, and the results of their research programme to date were discussed.

Co-operation in motorway fog studies

The Meteorological Office is co-operating with the Home Office, Transport and Road Research Laboratory and the Atomic Energy Research Establishment in a study which is related to fog on motorways. A Meteorological Office transmissometer has been set up alongside the M4 motorway near Theale, Berks., as a reference instrument for the evaluation of a number of cheaper and simpler visibility devices.

Hercules participates in GATE

The Hercules was delivered to the Meteorological Research Flight on 3 January. Before its departure for Dakar, Senegal, on 24 June, in order to participate in the GARP Atlantic Tropical Experiment of the World Meteorological Organization, about two months were spent on flight tests of the aircraft, two months on the installation of additional experimental instrumentation, and six weeks on flight testing experimental installations. During the first phase of GATE, the aircraft flew successfully on 10 missions of 8–10 hours duration each, in addition to three calibration flights. In general experimental instruments have functioned satisfactorily.

British infra-red detectors in NASA weather satellites

What have been described by the Goddard Space Center of the National Aeronautics and Space Administration as the first 1–1½-mile resolution pictures ever received from a weather satellite in synchronous orbit result from the development of cadmium-mercury-telluride, infra-red detector elements for use in a synchronous meteorological satellite (SMS) launched from Cape Canaveral on 15 May 1974.

The satellite's first work will be to watch the life cycle of short-lived storms that could form and die without ever being observed by satellites in a lower-altitude polar orbit.

The Visible Infra-red Spin-scan Radiometer (VISSR) provides day-time images of nearly one quarter of the earth's surface in 18 minutes. Pictures show such fine detail because each image contains 14 600 transmission lines compared with the normal 625-lines from standard United Kingdom television pictures.

Maps of wind direction and force for several levels in the atmosphere are made from time-lapse cloud motion measurements using the infra-red channels. The height of the observed wind velocity is deduced from the measurement of cloud-top temperature. This technique has proved useful during the GATE experiment.

The detectors were produced by Mullard at Southampton. Because of the extreme sensitivity of the detectors to minute changes in temperature, 'heat maps' of the earth's surface are taken by the SMS and transmitted back to earth to provide scientists with valuable meteorological and geological data. The detectors are most sensitive when they are cooled to low temperatures. This is achieved by a radiation cooler which allows any heat generated within the detector to leak into space. By use of this technique, temperatures lower than 100 kelvins (−173 °C) are made possible.

Laser radar installation at Beaufort Park

The large laser radar installation at Beaufort Park has been brought into operation and observations of Raman scattering from the stratosphere have been obtained. The results are encouraging as the number densities of air molecules calculated from the scattering data agree with those calculated from radiosonde observations in the region where the two methods of measurement overlap.

Building Climatology Section set up

A Building Climatology Section consisting of one Principal Scientific Officer and one Scientific Officer and funded by the Department of the Environment (DOE) has been set up in the Climatological Services Branch to work on projects specified by DOE.

Pressure data for the British Gas Corporation

A twice daily service of actual and forecast atmospheric pressure values has been supplied to the British Gas Corporation Liquid Natural Gas sites at Glen Mavis, Airdrie, since 27 February 1974 and Partington, Manchester, since 1 March 1974.

Contract for data buoy

The Department of Trade and Industry has placed a contract for the development and construction of the first United Kingdom national data buoy, DB-1. The Office is acting as design authority for the meteorological subsystem.

Analyses of WAMFLEX project

Analysis of data from the WAMFLEX project has now been completed; the object of the project was to measure the vertical transfer of horizontal momentum over large mountains (in this case the Rockies). Wind and temperature data secured by the Canberra when flying at a common flight level with other aircraft show perfect agreement with data from those aircraft, and flux profiles obtained from three aircraft flying in a 'stack' look reasonable. Significant transfers of momentum flux (0·3–0·5 N/m^2 at most levels) occurred on three days.

Transfer of radiation work

The transfer of all non-routine work on solar radiation and instrumentation from Kew Observatory to Beaufort Park was completed in January 1974.

Computerized radiosonde equipments

Contracts were placed with Ferranti, Wythenshawe, in March for the computerized station ground equipments and automated central calibration plant for the Mk 3 radiosonde system. The first ground station will be tested at Beaufort Park during the second half of 1975 while the central calibration plant will be brought into operation at Eastern Road during the same period.

Pollution sampling over the North Sea

In the Meteorological Office's study of the long-range transport of industrial pollution, a further series of sampling flights was carried out by Meteorological Research Flight in dry westerlies during August and September 1973. These included measurements of sulphate particles as well as sulphur dioxide gas. The analysis of the data, which has now been completed, leads to new estimates of approximately one-third for the fraction of sulphur pollution deposited on the ground before the air crossed the east coast. In the remainder of the programme the opportunity was taken of making similar measurements off the Danish and Norwegian coasts, with the aim of obtaining information on the further loss by deposition over the sea.

Computer Output Microfilm in the production of the *Monthly Weather Report*

Commencing with the January 1974 issue, printer's copy of the tabular material of the *Monthly Weather Report* has been in the form of Calcomp film. This new system will eliminate manual type-setting and proof reading. Calcomp-plotted charts are also being used in the production of the maps of mean air temperature, mean daily sunshine and 30-cm earth temperature anomaly maps although the isopleths are still drawn by hand.

Study of climatic variation

A study of climatic variation over the last few hundred years has revealed the inadequacies of inferring meteorological data from other associated data. For example a comparison of the temperature indications from the ^{18}O content of a Greenland ice core and from the dates of wine harvests in northern France with the central England series have indicated a rather low correlation. It seems unlikely that reliable decadal means for the time before instrumental temperature data can be derived from either of these sources.

The observed meteorological data indicate that over the last 250 years winter temperatures have increased slightly, but large fluctuations have occurred about the trend line.

CORRECTION

Meteorological Magazine, September 1974, p. 266, Table II. For 'Wokingham U.D.' read 'Woking U.D.'.

THE METEOROLOGICAL MAGAZINE

VOL. 104 NO. 1230 JANUARY 1975

CONTENTS

NOTICES

It is requested that all books for review and communications for the Editor be addressed to the Director-General Meteorological Office, London Road, Bracknell, Berkshire, RG12 2SZ, and marked 'For Meteorological Magazine'.

The responsibility for facts and opinions expressed in the signed articles and letters published in this magazine rests with their respective authors.

Printed in England by Heffers Printers Ltd, Cambridge
and published by
HER MAJESTY'S STATIONERY OFFICE

28p monthly **Annual subscription £3·84 including postage**
Dd. 506683 K16 1/75 ISBN 0 11 723068 5